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Research Article

Seaweed-Based Organic Fertilizer: Sargassum polycistum and Ulva lactuca as Green Innovations Supporting Environmental Policies

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Abstract

The West Coast is a coastal area rich in marine resources, including seaweed. The utilization of seaweed by the local community remains limited, primarily sold at low prices. The predominant seaweed species found in the West Coast area are *Sargassum polycistum* and *Ulva lactuca*. These two types of seaweed can be utilized as nutrient-rich, environmentally friendly organic fertilizers that benefit plants. This study aims to evaluate the quality of fertilizers derived from *Sargassum polycistum* and *Ulva lactuca* through the composting method. The data collected include physical and chemical observations. Physical quality observations cover aroma, color, texture, pH, and temperature, conducted from the seventh day until the compost is mature. Chemical quality tests of the organic fertilizer include measurements of total nitrogen (N), total phosphorus (P), total potassium (K), and organic carbon (C). The results were then compared with the compost quality standards outlined in SNI 19-7030-2004. The findings indicate that the best physical and chemical quality organic fertilizers meeting SNI standards were produced from the compositions of 5 kg *Ulva lactuca* + 700 mL EM4 and 5 kg *Sargassum polycistum* + 700 mL EM4.

Keywoards: Composting; Organic Fertilizer; *Sargassum polycistum*; *Ulva lactuca*; West Coast

INTRODUCTION

Seaweed, as an abundant biological resource in coastal areas, holds significant economic and ecological value. In various coastal regions, seaweed thrives and is easily accessible, making it a plentiful natural commodity that benefits local communities. In Indonesia, a country rich in marine biodiversity, seaweed grows abundantly and is readily available, serving as a valuable resource for the local population[1], [2]. Certain seaweed species, such as *Eucheuma cottonii*, have significant market potential and are used in a wide range of products, from food to cosmetics [3], [4]. Ecologically, seaweed plays a crucial role in maintaining the balance of marine ecosystems by absorbing excess nutrients that can cause eutrophication and degrade water quality[5]. Additionally, seaweed acts as a natural carbon sink, helping reduce carbon dioxide levels in water and supporting healthy marine habitats for various species[6]. The economic potential of seaweed continues to grow with the increasing demand for seaweed-based products. These products extend beyond food and health supplements to include raw materials for energy industries and organic fertilizers[2], [7]. Seaweed cultivation, such as in Dompu Regency, West Nusa Tenggara, demonstrates its potential as a significant source of income for local communities [4]. Thus, the development of seaweed-based industries not only provides economic benefits but also contributes to the sustainability of marine ecosystems [8].

In the context of sustainable agriculture, the use of seaweed as a raw material for organic fertilizers demonstrates significant potential to provide added value and positive impacts both economically and ecologically. Seaweeds such as *Sargassum polycistum* and *Ulva lactuca* are known for their high nutritional content, including essential nutrients like nitrogen, phosphorus, and potassium, as well as other important microelements that support soil and plant health [9], [10]. Organic fertilizers derived from these seaweeds can naturally enhance soil quality, improve soil structure, and increase water retention capacity without the negative impacts often associated with synthetic chemical fertilizers [10]. Additionally, the bioactive compounds in seaweed play a vital role in stimulating plant growth and strengthening resistance to diseases. This can directly reduce dependency on pesticides, addressing one of the major challenges in conventional agricultural practices [10].

The use of seaweed as a raw material for organic fertilizers not only supports agricultural productivity but also contributes to environmental conservation**.** Seaweed-based organic fertilizers can reduce dependence on chemical fertilizers, which often cause soil and water pollution. Research indicates that applying organic fertilizers, including those derived from seaweed, improves soil fertility and mitigates the negative effects of excessive chemical fertilizer use [11], [12]. Furthermore, seaweed-based fertilizers help maintain soil ecosystem balance by enhancing soil quality and supporting microbial diversity, which is essential for ecosystem health[13]. By reducing chemical fertilizer use, which can lead to environmental degradation such as pollution and soil quality decline, seaweed-based fertilizers align with environmental policies aimed at minimizing the negative impacts of agricultural activities [14]. Developing seaweed-based fertilizers is thus highly relevant in the context of sustainable agriculture. Studies show that combining organic fertilizers with reduced chemical fertilizers can increase crop yields without compromising soil quality[15], [16]. Therefore, adopting seaweed-based

organic fertilizers presents an effective strategy to boost agricultural productivity while preserving environmental sustainability [17].

Indonesia, with its extensive coastline and diverse seaweed species, holds great potential for utilizing seaweed in sustainable and economical organic fertilizer innovations. Seaweed is rich in nutrients beneficial for plant growth, and previous research has indicated that its use as a fertilizer can improve soil fertility and support more environmentally friendly agriculture[18]. This green innovation not only promotes sustainable agricultural practices but also aligns with broader environmental policies. By sustainably utilizing coastal resources such as seaweed, dependence on chemical fertilizers which often harm the environment can be reduced [19]Research by Sari et al. highlights that allelochemical compounds from plants can be used as organic fertilizers, consistent with efforts to mitigate the negative impacts of chemical fertilizers [18]. This study aims to explore the effectiveness of seaweed as an organic fertilizer to support green environmental policies through composting methods. By understanding the benefits of seaweed-based fertilizers, it is hoped to establish agricultural practices that are not only productive but also sustainable, in harmony with improved natural resource management policies. This research is expected to provide deeper insights into the contribution of seaweed in creating healthy and sustainable agricultural ecosystems [20].

METHODS

The collection of seaweed and the production of fertilizer were conducted in Cahaya Negeri Village, Pesisir Barat Regency. The compost quality testing was carried out at the Soil Science Laboratory, Universitas Lampung. This research was conducted from September to November 2020, employing a qualitative approach with a descriptive method. The chemical quality of compost produced from *Sargassum polycistum* and *Ulva lactuca* through the composting method was evaluated and compared against the standards outlined in SNI 19-7030-2004.

Gambar 1: A. *Sargassum polycistum;* B. *Ulva lactuca*

The composition of organic fertilizer developed in this study was modified from Budiyani's research (2013) and is presented in the following table:

Table 1. Composition of Organic Fertilizer

Code	Seaweed Type	Seaweed Quantity	Additive	Additive Quantity	EM4 Volume
S1	*Sargassum polycistum*	5 kg	Dedak	1 kg	700 mL
S2	*Sargassum polycistum*	5 kg	Dedak	1 kg	500 mL
S3	*Sargassum polycistum + Ulva lactuca*	5 kg	Dedak	1 kg	700 mL
U1	*Ulva lactuca*	5 kg	Dedak	1 kg	700 mL
U2	*Ulva lactuca*	5 kg	Dedak	1 kg	500 mL
U3	*Sargassum polycistum + Ulva lactuca*	5 kg	Dedak	1 kg	500 mL

Note: S: *Sargassum polycistum;* U: *Ulva lactuca*

The addition of rice bran serves to accelerate the decomposition process and provides nutrients with a composition of 86.5% dry matter, 8.7% ash, 10.8% crude protein, 1.5% crude fiber, as well as 0.2% calcium (Ca) and 2.5% phosphorus (P)[21].

Organic Fertilizer Production

This research began with the preparation and production of organic fertilizer. Sargassum polycistum and Ulva lactuca seaweed were directly collected from Cahaya Negeri Beach in Lemong District, Pesisir Barat Regency. The seaweed was repeatedly washed to remove salt, shells, and other impurities, then dried under the sun for 4–5 hours and chopped into 2 cm pieces to facilitate decomposition. Half a bottle of EM4 and half a kilogram of granulated sugar were dissolved in 6 liters of water and left overnight. This EM4 solution was gradually mixed with rice bran according to the treatment levels and stirred until homogeneous. The mixture of seaweed, rice bran, and EM4 was then placed into sacks for composting, which lasted for one month. The mixture was stirred weekly to aid the decomposition process.

Compost Quality Testing

The C-organic content was determined using the Walkey and Black method through titration with ferrous sulfate. A 0.5 g sample of fine compost was weighed and placed into a 250 mL volumetric flask, followed by the addition of 1 N $K_2Cr_2O_7$ and 10 mL concentrated H_2SO_4, then left for 30 minutes. Subsequently, 100 mL distilled water, 5 mL 85% phosphoric acid, 5 mL NaF, and 15 drops of diphenylamine indicator were added, and the mixture was titrated with ferrous sulfate until the solution turned green. The titration volume was then recorded.

The total nitrogen content was measured using the Kjeldahl method. A 0.5 g fertilizer sample was placed in a Kjeldahl flask, combined with 25 mL of sulfuric acid-salicylic acid solution, and left overnight. The following day, 4 g $Na_2S_2O_3$ was added, and the mixture was gradually heated to a maximum temperature of 300°C. The extract was transferred, diluted, and a 25 mL aliquot was pipetted, mixed with 150 mL distilled water, 10 mL 40% NaOH solution, and boiling stones. The

resulting distillate was collected in a container containing boric acid and titrated with 0.5 N H_2SO_4 to determine the total nitrogen content.

The total phosphorus (P) content was measured using the 25% HCl extraction method. A 1 g compost sample was mixed with 25 mL of 25% HCl in a shaking bottle, stirred for 1 hour, filtered, and measured with a spectrophotometer. Finally, the potassium content was analyzed using an Atomic Absorption Spectrophotometer (AAS) after a 0.1 g sample was diluted and heated until the solution became clear.

Data Analysis

The measured data included physical and chemical observations. Physical quality was assessed based on aroma, color, texture, pH, and temperature from the seventh day until the compost was fully matured. Chemical quality tests included measurements of total nitrogen (N), total phosphorus (P), total potassium (K), and C-organic. These observations were compared against the compost quality standards outlined in SNI 19-7030-2004. The analysis of the physical and chemical quality tests of the organic fertilizer was presented in tables, graphs, and images, analyzed descriptively and qualitatively, and compared with the quality standards of SNI 19-7030-2004.

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RESULT AND DISCUSSIONS

This study aims to evaluate the quality of organic fertilizer produced from *Sargassum polycistum* and *Ulva lactuca*using the composting method. The process began with the preparation of the EM4 activator, composed of 300 mL EM4, 300 grams of granulated sugar, and 3 liters of water. This solution was mixed in a tightly sealed container and left overnight to activate and multiply the microorganisms within. The EM4 activator was prepared twice during the study. Seaweed collection for *Sargassum polycistum* and *Ulva lactuca* was conducted in the morning. The seaweed was weighed according to the required amounts, thoroughly washed to remove dirt, shells, and salt, and then sun-dried for approximately 4 hours. Once dried, the seaweed was chopped into small pieces (2–3 cm) to facilitate the decomposition process. The EM4 activator was gradually added to the chopped seaweed while stirring to ensure even distribution. The mixture was then placed in sacks tied securely with raffia rope and set on plastic tarps lined with wooden boards, covered with another tarp. During the composting process, the pile of fertilizer was turned weekly to ensure uniform decomposition and to accelerate the breakdown of organic matter into smaller particles. This procedure is expected to produce high-quality organic fertilizer.

Physical Quality

The physical data, including parameters such as color, texture, aroma, and temperature, were recorded weekly and are presented in Figure 2.

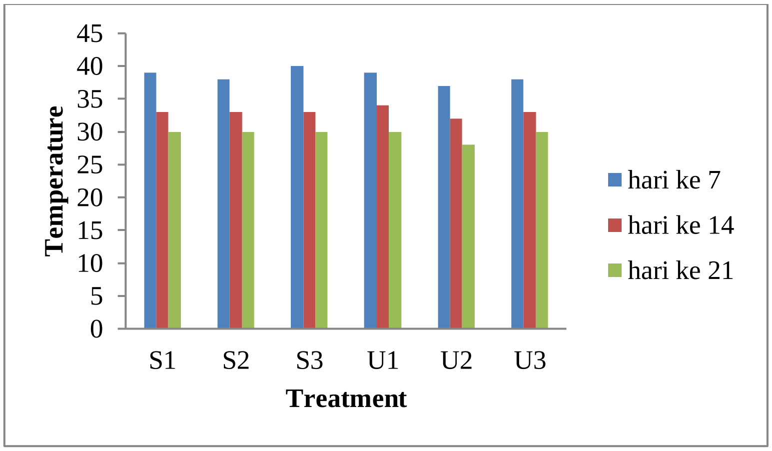

Figure 2. Observed Temperature During the Composting Process

Figure 2 illustrates temperature data for various treatments during the composting process. It can be concluded that the initial temperature during the first week ranged between 37°C and 40°C, indicating intense microbial activity at the beginning of the decomposition process. Composting was optimal up to the seventh day due to increased microbial activity in breaking down organic matter [22]. In the second week, the temperature decreased to 32°C–34°C, signaling a decline in microbial activity as the process progressed. By the third week, the temperature stabilized at 28°C–30°C, suggesting that the decomposition process was nearing completion. Towards the end of composting, the temperature further decreased to 29°C–34°C, aligning with ambient environmental temperatures [23]. The temperature rise was also influenced by mesophilic microorganisms, which thrive optimally in the 30°C–40°C range, such as *Actinomycetes* present in EM4. The more EM4 added, the higher the number of microbes in the sample[24]. Overall, all treatments showed a similar pattern of temperature decline, consistent with the normal characteristics of the composting process. The temperature decrease occurred as the organic matter in the compost broke down and diminished [25]. The compost temperature met SNI parameters, reflecting the temperature of groundwater. This indicates conditions suitable for absorption by plant roots in an aerobic environment and does not exceed 30°C [26].

Table 2. Observed Compost Texture Results

No	Treatment	Observation Week		
		1	2	3
1	S1	Decomposed, seaweed pieces still visible	Starting to decompose	Fine
2	S2	Slightly decomposed, seaweed still visible	Decomposed, few seaweed pieces still visible	Fine
3	S3	Beginning to decompose, seaweed still visible	Decomposed, few seaweed pieces still visible	Fine
4	U1	Beginning to decompose, seaweed still visible	Decomposed, few seaweed pieces still visible	Appears finer

No	Treatment	Observation Week		
		1	2	3
5	U2	Beginning to decompose, seaweed still visible	Decomposed, few seaweed pieces still visible	Appears finer
6	U3	Beginning to decompose, seaweed still visible	Decomposed, few seaweed pieces still visible	Fine

The texture observation data during the composting process in Table 2 shows similar progress across all treatments. In the first week, the materials began to decompose, but pieces of seaweed were still visible, especially in treatments S2 and S3, which exhibited slower decomposition compared to the others. By the second week, most materials had decomposed, although small pieces of seaweed were still noticeable. In the third week, all treatments resulted in a fine texture, with treatments U1 and U2 producing slightly finer results compared to the others. Overall, the composting process successfully produced fine-textured fertilizer by the third week. All five treatments resulted in organic fertilizer textures that met SNI standards—fine, crumbly, and soil-like. This was achieved because the raw materials were chopped prior to composting, facilitating faster decomposition by microorganisms. Smaller material sizes accelerate the maturation process due to the increased surface area available for decomposing bacteria [27].

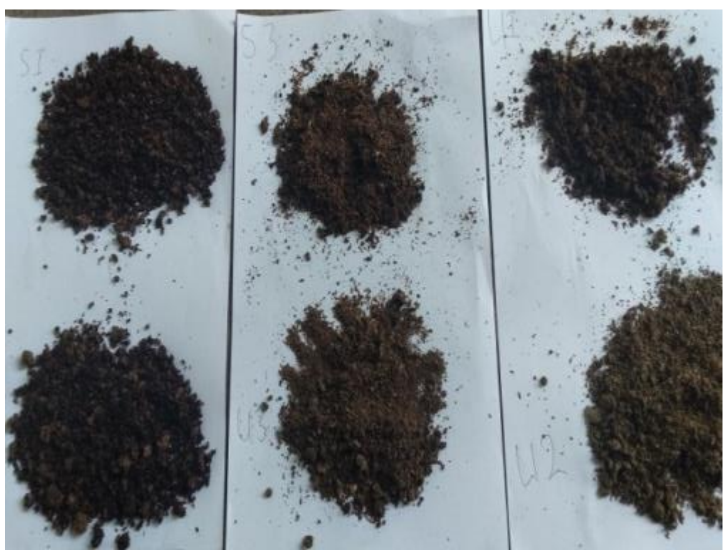

Figure 3. Color of Compost from S*argassum polycistum* and *Ulva lactuca*

Table 3. Observations of Compost Color

No	Treatment	Observation Week		
		1	2	3
1	S1	Brown	Dark Brown	Blackish Brown
2	S2	Brown	Dark Brown	Blackish Brown
3	S3	Brown	Dark Brown	Blackish Brown
4	U1	Seaweed color (green)	Brownish	Blackish Brown
5	U2	Seaweed base color (green)	Slightly seaweed color visible	Slightly brownish
6	U3	Brown with a slight green hue	Brownish	Brown

Figure 3 and Table 3 illustrate that the composting process resulted in a gradual darkening of the compost color over time. In the first week, most treatments exhibited a brown color, with some still displaying the seaweed's base color (green), particularly in treatments using *Ulva lactuca*. By the second week, the compost's color transitioned to dark brown or brownish, indicating active decomposition. In the third week, all treatments showed blackish-brown or brown hues, signifying that the organic matter had decomposed effectively. This darkening of the color is a common indicator of successful composting, with the final product being ready for use. Mature compost typically possesses physical properties similar to soil and humus, characterized by a dark color and crumbly texture. This coloration is influenced by the activator used, which accelerates the composting process [27].

Table 4. Observations of Compost Aroma

No	Treatment	Observation Week		
		1	2	3
1	S1	Seaweed aroma	Slight seaweed aroma	Soil-like
2	S2	Seaweed aroma	Slight seaweed aroma	Soil-like
3	S3	Seaweed aroma	Slight seaweed aroma	Soil-like
4	U1	Seaweed aroma	Slight seaweed aroma	Soil-like
5	U2	Seaweed aroma	Slight seaweed aroma	Slightly soil-like
6	U3	Seaweed aroma	Slight seaweed aroma	Soil-like
		Seaweed aroma	Slight seaweed aroma	Soil-like

Table 4 generally illustrates the observed changes in compost aroma during the composting process. In the first week, all treatments still emitted a seaweed aroma. By the second week, the seaweed aroma began to diminish, although it was still slightly noticeable. In the third week, most treatments had developed a soil-like aroma, indicating that decomposition had progressed optimally. The only exception was treatment U2, which still had a slightly soil-like smell but showed progress toward mature compost conditions. These changes in aroma reflect the maturity of the compost, which is ready for use. Low moisture content influences the compost's aroma. The faster the compost changes to a blackish-brown color, the quicker the unpleasant odors disappear. This transformation in aroma indicates the ongoing decomposition process. Over time, the initial foul smell during composting diminishes and is replaced by a soil-like aroma, signifying that the compost is mature [28].

Chemical Quality

The observed nutrient contents of N, P, K, and C-organic in the compost from treatments S1, U1, and S3 were higher than the Indonesian National Standard (SNI) values (Table 5). The nitrogen content (Total N) in all treatments exceeded the SNI standard of 0.40%, with the highest value observed in treatment S3 at 1.09%. The high nitrogen content reflects more optimal decomposition, supported by microbial activity that breaks down proteins into amino acids, ammonium, and nitrate. Nitrogen plays a crucial role in vegetative plant growth, such as stems, leaves, and roots, and aids in protein and chlorophyll formation. However, excessive nitrogen application can hinder flowering and fruiting, so its use must align with the plant's needs. Balanced nitrogen fertilization enhances plant growth, but excessive doses can result in excessive vegetative growth and reduced crop yields [29], [30]. Interactions between nitrogen and other nutrients, such as potassium, also contribute to improving crop yields [31].

Table 5. Contents of N, P, K, and C-Organic

No	Parameter	S1 (%)	U1 (%)	S3 (%)	Indonesian National Standard (%)
1	N- Total	0,97	0,98	1,09	0,40
2	P- Total	0,36	0,36	0,31	0,1
3	K –Total	2,41	2,84	1,22	0,20
4	C – Organic	27,11	22,37	23,13	9,8
5	pH	6,38	6,32	7,08	6, 80 – 7,49

Phosphorus (P-Total)

The phosphorus content (P-Total) in the compost ranged from 0.31% to 0.36%, exceeding the SNI standard of 0.10%. The phosphorus levels in compost are influenced by the raw materials, microbial activity, and the organic matter decomposition process. During compost maturation, microorganisms may consume phosphorus, potentially reducing its levels if composting takes too long[32]. Microorganisms play a vital role in organic matter decomposition and phosphate solubilization, affecting phosphorus availability for plants. Organic matter decomposition and natural mineral weathering also contribute to phosphorus availability in compost. However, phosphorus derived from mineral weathering often binds with other soil elements, making it less accessible to plants despite its abundance[32]. Compost rich in phosphorus can enhance the growth and yield of crops like peanuts and corn [33].

Potassium (K-Total)

The potassium content (K-Total) was significantly higher than the SNI standard, with the highest level observed in treatment U1 at 2.84%, compared to the standard of 0.20%. Potassium levels in compost are strongly influenced by the raw materials used, with organic matter like *Ulva lactuca* known for its high potassium content. During composting, microorganisms enhance potassium levels by decomposing organic matter, producing potassium compounds easily absorbed by plants. This process is also influenced by the cation exchange capacity of organic matter, which increases potassium

availability in the soil. Research has shown that compost made from *Ulva lactuca* improves nutrient availability, including potassium, essential for plant growth[34]. Potassium plays a crucial role in supporting plant growth, increasing physical strength, and enhancing resistance to pests and diseases. Its application in agriculture improves pest resistance and influences plant growth and overall yield[35]. Therefore, compost containing *Ulva lactuca* is a viable alternative to enhance soil quality and support sustainable plant growth[36]. A well-managed composting process, particularly with raw materials like *Ulva lactuca*, yields high-quality compost with optimal potassium levels, essential for healthy and productive plant growth[37].

C-Organic and pH Levels

The C-Organic content in all treatments ranged from 22.37% to 27.11%, significantly higher than the SNI standard of 9.8%, indicating high potential for improving soil quality. C-Organic is critical in soil ecosystems, supporting microbial activity responsible for organic matter decomposition. Microbial-driven decomposition not only releases nutrients needed by plants but also improves soil structure through cation exchange capacity, a key indicator of compost maturity[38]. The use of rice bran during composting plays a crucial role in providing the carbon needed for microbial growth. This carbon supports the formation of organic compounds from carbohydrate-rich compost materials. Moisture levels and organic matter composition, including rice bran, significantly influence composting outcomes, as microorganisms require carbon for efficient decomposition[39]. The use of rice bran in organic waste processing improves efficiency in producing high-quality organic fertilizers [40]. The pH levels across all treatments were close to the SNI standard range (6.80–7.49). Treatments S1 and U1 slightly fell below the standard range, while treatment S3 (*Sargassum polycistum* and *Ulva lactuca* + 700 mL EM4) met the range. Overall, compost from all treatments demonstrated good quality and met the nutrient standards for compost as defined by SNI.

CONCLUSION

The results of the study indicate that the best physical and chemical quality organic fertilizer, meeting SNI standards, was produced from the composition of Ulva lactuca (5 kg) + EM4 (700 mL) and Sargassum polycistum (5 kg) + EM4 (700 mL).

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AUTHORS CONTIBUTIONS

All authors are major contributors in this research. AUM, RL, and SMP collaborated to design the research and write the initial research draft. RL: executed the experiment, AUM: wrote the article draft and revised the draft, SMP: contributed suggestions for article improvement

CONFLICT OF INTEREST

The authors declare no conflict of interest. This research, including the selection of the research project, study design, data collection, analysis, interpretation, manuscript writing, and decision to publish, was conducted independently and without any external influence or funding sponsor involvement.

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